

That which is claimed is:

1. An integrated process for producing LNG and GTL products comprising the steps of:

cooling natural gas in at least one cooling step so as to provide a cooled natural gas stream;

processing said cooled natural gas stream in at least two expansion/separation cycles, each expansion/separation cycle comprising the Substeps of:

a. isentropically or isenthalpically expanding at least a portion of said cooled natural gas steam and producing a natural gas vapor component and a LNG component;

b. separating at least a portion of said natural gas vapor component from said LNG component; and

c. repeating Substeps a. through b.,

wherein at least a portion of said LNG component from said previous expansion/separation cycle is directed to each successive Substep a.,

wherein said final LNG product is said LNG component after said final separating step and is substantially liquid at substantially atmospheric pressure; and

converting at least a portion of one or more of said expansion/separation cycle natural gas vapor components into a GTL product.

2. The integrated process of Claim 1 wherein each of said expansion/separation cycles comprise an isenthalpic expansion of said cooled natural gas streams and said LNG components across a Joule Thompson valve wherein the pressure of said cooled natural gas stream and each successive LNG component are each reduced by at least 15 psig.

3. The integrated process of Claim 1 wherein said first expansion/separation cycle comprises reducing the pressure of said cooled natural gas stream by at least 30 psig and reducing the temperature of such cooled natural gas stream by at least 10 °F.

4. The integrated process of Claim 1 wherein the expanded pressure of said natural gas vapor component and said LNG component from said first expansion/separation cycle step is not less than 75 psia and wherein at least a portion of said natural gas vapor component from said first expansion/separation cycle is directed to said converting step.

5. The integrated process of Claim 1 wherein said converting step further comprises:

a pre-reforming step for reducing the molar concentration of ethane and higher boiling point hydrocarbon in said natural gas vapor components and producing a pre-reformed natural gas vapor;

a reforming step for converting at least a portion of said pre-reformed natural gas vapor to synthesis gas;

a downstream GTL product conversion step for converting said synthesis gas into at least one GTL product and a stream of unconverted synthesis gas; and

a recycling step wherein at least a portion of said stream of unconverted synthesis gas is recycled to either said pre-reforming step or said reforming step;

5 wherein at least a portion of one or more of said natural gas vapor components is directed to at least one step selected from the group consisting of said pre-reforming step, said reforming step, and said recycling step.

10 6. The integrated process of Claim 5 wherein said recycling step comprises a compression step for recycling said stream of unconverted synthesis gas and said one or more of said natural gas vapor components is added upstream of said compression step.

15 7. The integrated process of Claim 1 wherein at least a portion of said GTL product is at least one member selected from the group consisting of products of a Fischer Tropsch reaction, methanol, and dimethyl ether.

20 8. The integrated process of Claim 1 wherein said at least two expansion/separation cycles are conducted without a processing step for separation and removal of NGL's.

25 9. An integrated process for producing LNG and GTL products comprising:

cooling natural gas in at least one cooling step so as to provide a cooled natural gas stream;

30 isentropically or isenthalpically expanding at least a portion of said cooled natural gas steam in a first expansion step and producing a first natural gas vapor component and a first LNG component;

separating at least a portion of said first natural gas vapor component from said first LNG component;

isentropically or isenthalpically expanding at least a portion of said first LNG component in a second expansion step and producing a second natural gas vapor component and a second LNG component;

separating at least a portion of said second natural gas vapor component from said second LNG component; and

converting at least a portion of one or more of said first and second natural gas vapor components into a GTL product.

10. The integrated process of Claim 9 wherein said first and second expansion steps each comprise an isenthalpic expansion of said cooled natural gas stream and said first LNG component across a Joule Thompson valve wherein the pressure of said cooled natural gas stream and said first LNG component are each reduced by at least 15 psig.

11. The integrated process of Claim 9 wherein said first expansion step comprises reducing the pressure of such cooled natural gas stream by at least 30 psig and reducing the temperature of such cooled natural gas stream by at least 10 °F.

12. The integrated process of Claim 9 wherein said first natural gas component comprises a higher mole percent of nitrogen and a lower mole percent of ethane and all higher boiling point hydrocarbon than said cooled natural gas stream.

13. The integrated process of Claim 9 wherein said second LNG product is substantially liquid at substantially atmospheric pressure.

14. The integrated process of Claim 9 wherein the expanded pressure of said first expansion step is not less than 75 psia and wherein at least a portion of said first natural gas vapor component is directed to said converting step.

5 15. The integrated process of Claim 9 wherein said converting step further comprises:

10 a pre-reforming step for reducing the molar concentration of ethane and higher boiling point hydrocarbon in said first or second natural gas vapor components and producing a pre-reformed natural gas vapor;

a reforming step for converting at least a portion of said pre-reformed natural gas vapor to synthesis gas;

15 a downstream GTL product conversion step for converting said synthesis gas into at least one GTL product and a stream of unconverted synthesis gas; and

20 a recycling step wherein at least a portion of said stream of unconverted synthesis gas is recycled to either said pre-reforming step or said reforming step;

25 wherein at least a portion of said first or second natural gas vapor components is directed to at least one step selected from the group consisting of said pre-reforming step, said reforming step, and said recycling step.

30 16. The integrated process of Claim 15 wherein said recycling step comprises a compression step for recycling said stream of unconverted synthesis gas and at least a portion of said first or second natural gas vapor component is added upstream of said compression step.

17. The integrated process of Claim 15 wherein at least a portion of said first natural gas vapor component becomes a fuel source for at least one member selected from the group consisting of a LNG refrigeration compressor and said reforming step.

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18. The integrated process of Claim 9 wherein at least a portion of said GTL product is at least one member selected from the group consisting of products of a Fischer Tropsch reaction, methanol, and dimethyl ether.

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19. The integrated process of Claim 9 wherein said first and second expansion steps and any processing steps conducted therebetween are conducted without a processing step for separation and removal of NGL's.

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20. An integrated process for producing LNG and GTL products comprising:

cooling natural gas in at least one cooling step so as to provide a cooled natural gas stream;

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isentropically or isenthalpically expanding at least a portion of said cooled natural gas steam in a first autorefrigeration step and producing a first natural gas vapor component and a first LNG component;

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separating at least a portion of said first natural gas vapor component from said first LNG component;

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isentropically or isenthalpically expanding at least a portion of said first LNG component in a second autorefrigeration step and producing a second natural gas vapor component and a second LNG component;

separating at least a portion of said second natural gas vapor component from said second LNG component;

compressing at least a portion of one or more of said first and second natural gas vapor components and producing a compressed natural gas feedstock having a higher temperature than either of said first and second natural gas vapor components; and

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converting at least a portion of said compressed natural gas feedstock to a GTL product.

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21. The integrated process of Claim 20 wherein the expanded pressure of said first expansion step is not less than 75 psia and wherein at least a portion of said first natural gas vapor component is directed to said converting step.

22. The integrated process of Claim 20 wherein:

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the temperature of said cooled natural gas stream is not more than -20 °F;

the temperature of said cooled natural gas stream is reduced by at least 3 °F in said first autorefrigeration step; and

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the temperature of said second natural gas vapor component is at least 3 °F below that of said first LNG component.

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23. The integrated process of Claim 20 wherein said first and second autorefrigeration steps each comprise an isenthalpic expansion of said cooled natural gas stream and said first LNG component across a Joule Thompson valve wherein the pressure of said cooled natural gas stream and said first LNG component are each reduced by at least 15 psig.

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24. The integrated process of Claim 20 wherein said first autorefrigeration step comprises reducing the pressure of such cooled natural gas stream by at least 30 psig and reducing the temperature of such cooled natural gas stream by at least 10 °F.

25. The integrated process of Claim 20 wherein said converting step further comprises:

5 a pre-reforming step for reducing the molar concentration of ethane and higher boiling point hydrocarbon of said compressed natural gas feedstock and producing a pre-reformed natural gas feedstock;

10 a reforming step for converting at least a portion of said pre-reformed natural gas feedstock to synthesis gas;

15 a downstream conversion step comprising at least one reaction step selected from the group consisting of conversion of synthesis gas to hydrogen, conversion of synthesis gas to methanol, conversion of synthesis gas to dimethyl ether, and conversion of synthesis gas to a product of a Fischer Tropsch reaction, said downstream conversion step converting said synthesis gas into said GTL product and a stream of unconverted synthesis gas; and

20 a recycling step wherein at least a portion of said stream of unconverted synthesis gas is recycled to either said pre-reforming step or said reforming step;

25 wherein at least a portion of said compressed natural gas feedstock is directed to at least one step selected from the group consisting of said pre-reforming step, said reforming step, and said recycling step.

30 26. The integrated process of Claim 20 wherein said first and second autorefrigeration steps and any processing steps conducted therebetween are conducted without a processing step for separation and removal of NGL's.

27. An integrated process for producing LNG and GTL products comprising:



cooling natural gas in at least one cooling step so as to provide a cooled natural gas stream;

5 isentropically or isenthalpically expanding at least a portion of said cooled natural gas stream in a first autorefrigeration step and producing a first natural gas vapor component and a first LNG component;

10 separating at least a portion of said first natural gas vapor component from said first LNG component;

15 isentropically or isenthalpically expanding at least a portion of said first LNG component in a second autorefrigeration step and producing a second natural gas vapor component and a second LNG component;

separating at least a portion of said second natural gas vapor component from said second LNG component;

20 isentropically or isenthalpically expanding at least a portion of said second LNG component in a third autorefrigeration step and producing a third natural gas vapor component and a LNG product;

25 separating at least a portion of said third natural gas vapor component from said LNG product; and

converting at least a portion of one or more of said first, second and third natural gas vapor components into a GTL product.

30 28. The integrated process of Claim 27 wherein said LNG product is substantially liquid at substantially atmospheric pressure.

29. The integrated process of Claim 27 wherein said portion of one or more of said first, second and third natural gas vapor components is compressed

producing a compressed GTL feedstock having a higher temperature than any of said first, second and third natural gas vapor components exiting said first, second and third autorefrigeration steps.

5           30.    The integrated process of Claim 27 wherein at least a portion of either or both of said first or second natural gas vapor components is converted into GTL product and at least a portion of said third natural gas vapor is compressed, refrigerated and directed to any one or more of said cooled natural gas stream, said first LNG component, said second LNG component,  
10           or said LNG product.

          31.    The integrated process of Claim 27 wherein said first and third autorefrigeration steps and any processing steps conducted therebetween are conducted without a processing step for separation and removal of NGL's.  
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          32.    A LNG product produced by a process comprising the steps of:

          cooling natural gas in at least one cooling step so as to provide a cooled natural gas stream;  
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          processing said cooled natural gas stream in at least two expansion/separation cycles, each expansion/separation cycle comprising the Substeps of:

25           a.    isentropically or isenthalpically expanding at least a portion of said cooled natural gas stream and producing a natural gas vapor component and a LNG component;

          b.    separating at least a portion of said natural gas vapor component  
30           from said LNG component; and

          d.    repeating Substeps a. through b.,

wherein at least a portion of said LNG component from said previous expansion/separation cycle is directed to each successive Substep a., and

5 wherein said final LNG product is said LNG component after said final separating step and is substantially liquid at substantially atmospheric pressure; and

10 converting at least a portion of one or more of said expansion/separation cycle natural gas vapor components into a GTL product.

33. The LNG product of Claim 32 wherein said LNG product comprises:

15 not more than 2.0 mole percent of nitrogen;

not more than 1.0 mole percent of helium; and

20 not more than 18 mole percent of the total of ethane and all hydrocarbons having a boiling point greater than ethane.

34. The LNG product of Claim 32 wherein the heating value of said LNG product is at least 1000 Btu/scf and not more than 1200 Btu/scf.

25 35. The LNG product of Claim 32 wherein said LNG product comprises:

not more than 0.3 mole percent of nitrogen;

not more than 0.2 mole percent of the total of helium; and

30 not less than 18 mole percent of the total of ethane and all hydrocarbons having a boiling point greater than ethane.

36. The LNG product of Claim 35 wherein the heating value of said LNG product is not less than 1200 and not more than 1600.

37. The LNG product of Claim 35:

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wherein said converting step comprises converting at least a portion of said natural gas vapor component into Fischer Tropsch reaction products;

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wherein at least a portion of said Fischer Tropsch reaction products directly or after subsequent processing of said Fischer Tropsch reaction products, comprises at least one heavier hydrocarbon selected from the group consisting of ethane, propane, and butane; and

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wherein said LNG product comprises at least a portion of said at least one heavier hydrocarbon produced from said converting step.

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